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THE CONTAINMENT OF BLAST EFFECTS FROM THE DETONATION OF SMALL HIGH EXPLOSIVE CHARGES

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August 1981

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
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A spherical containment device to be used for the safe transportation of high explosives was evaluated for its ability to suppress blast effects from internal explosive detonations of charge weights extending to 483 gms (17.03 oz.) of 50/50 pentolite explosive. The device consisted of a steel sphere with a specially designed port to permit the placement of high explosive material inside. In a series of tests, charges of different weights were detonated inside the device. Overpressure measurements were recorded at 61 cm. from the outside surface and pressure measurements were made on the interior. The strain expe-
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experienced by the sphere was measured on the outside surface. The study demonstrated that the design criterion has been met since the device was capable of containing the explosive gases and restricting the exterior overpressure below the threshold for human ear drum rupture.

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I. INTRODUCTION

A Suppressive Shield Program was instituted for the purpose of advancing the technology for providing cost effective protection against various hazard parameters in munition assembly operations. The hazard parameters were categorized with regard to the potential severity of blast effects and of fragmentation damage. This study is for the category where the hazard from blast effects can be severe, but the fragment damage is assumed to be light.

A suppressive shield, shown in Figure 1, was designed to permit safe local transport of small size high explosive charges. If the charges being transported are accidentally detonated, the shield is required to mitigate the blast effects to insure the safety of nearby personnel. The suppressive shield must maintain its integrity (no rupture) during a detonation and minimize the exterior acoustic pressure level such that eardrum rupture cannot occur.

The prototype of the suppressive shield was constructed by Aircraft Armaments, Inc, of Cockeysville, Maryland on the basis of design information provided by the Southwest Research Institute and the Edgewood Arsenal. The prototype was shipped to the Ballistic Research Laboratory for the purpose of evaluating its ability to perform within the design criteria.

The design criteria consisted of two parts:

1. The suppressive shield had to contain the blast produced by the detonation of 19 high explosive charges, each weighing 14 g (0.494 oz). To meet DARCOM safety approval requirements, which included a 25% safety margin, the maximum number of high explosive charges was increased to 24 for the purpose of this study.

2. The blast overpressure at 61 cm (24 in.) from the suppressive shield's exterior surface had to be less than 34.5 KPa (5 psi), which is the threshold for human eardrum rupture.[1]

The evaluation consisted of subjecting the prototype suppressive shield to a series of internal high explosive detonations and, based on the test results, assessing the shield's capability to meet these requirements.

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[1] *"Structures to Resist the Effects of Accidental Explosives", TM5 - 1300, Departments of the Army, Navy, and Air Force, June 1969.*

Figure 1: The Prototype of The Suppressive Shield For Transporting Small High Explosives Charges

II. A DESCRIPTION OF THE SPHERICAL CONTAINMENT DEVICE

The suppressive shield is a spherical container consisting of two hemispheres welded together (see Figure 2). The inside diameter of the shell is 61 cm (24 inches) and the shell thickness is 0.635 cm (0.25 inches). The hemispheres are constructed of 1020 mild steel. The welded seam between the hemispheres is strengthened by two reinforcing bands. One band is welded on the exterior side of the upper hemisphere and the other band is welded on the interior side of the lower hemisphere. The exterior band is 2.54 cm (1 inch) wide and has a thickness of 0.635 cm (0.25 inches). The interior band is 8.9 cm (3.5 inches) wide and has a thickness of 1.27 cm (0.5 inches). The orientation of the suppressive shield is such that the welded seam is located in a horizontal plane.

Access to the interior of the suppressive shield is permitted by a circular port cut into the upper hemisphere. The port is located so that its center is 45 degrees above the welded seam. The diameter of the port is 19 cm (7.5 inches). The port is reinforced by a steel ring welded around its edge. The steel ring is 1.9 cm 0.75 inches) thick and has an outside diameter of 26.7 cm(10.5 inches). The port has a door which is hinged at the top of the port and on the inside. If an explosion should occur the internal pressure will tend to seal the door. The amount of sealing is enhanced by a gasket placed around the edge of the door. The door is 0.953 cm (0.375 inches) thick and has a diameter of 20.3 cm (8.0 inches) which is larger than the diameter of the port.

The explosive charges are placed in the suppressive shield on a circular revolving platform The diameter of the platform is 48.26 cm (19 inches). When in place, the centers of mass of the charges are located approximately in the plane of the welded seam. The platform is supported by a section of steel tubing welded to the bottom of the lower hemisphere, with the tubing located in the vertical plane which bisects the sphere in the longitudinal direction. The diameter of the steel tubing is 2.54 cm (1.0 inches).

III. INSTRUMENTATION

The instrumentation consisted of four piezoelectric pressure transducers and two strain gauges. The signals from the pressure transducers were conditioned and amplified using a GATX Model GL 102 wideband signal conditioner. An Endevco Model 4470 signal conditioning system provided this same function for the two strain gauge signals. The data were recorded on a Honeywell Model 7600 FM magnetic tape recorder at a tape speed of 304.8 cm/sec. (120 inches/sec.). The parameters which were measured and the corresponding recording channel assignments are listed in Table 1.

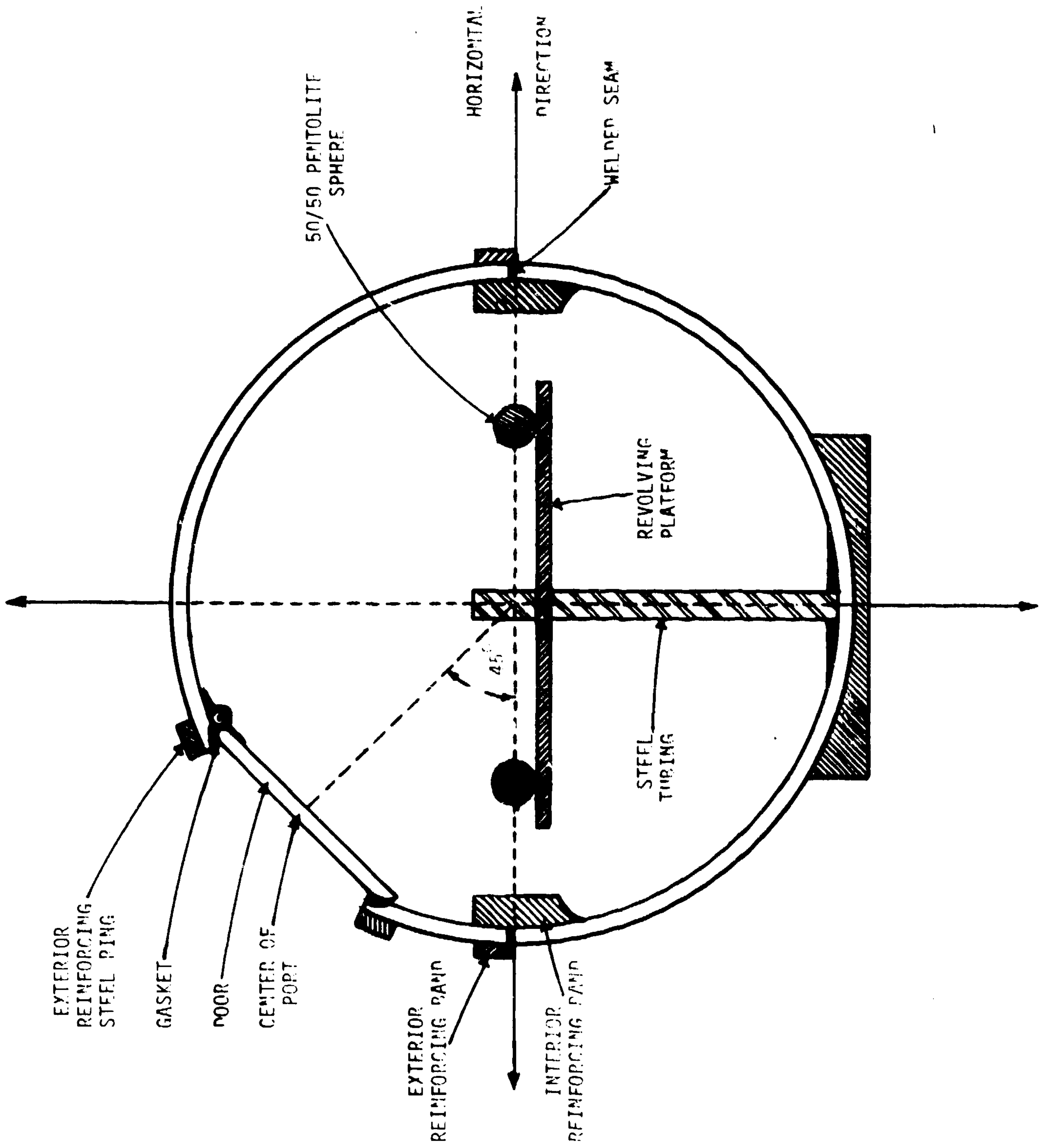

Figure 2: The Interior Geometry And Components Of The Suppressive Shield

TABLE I. THE RECORDING CHANNEL ASSIGNMENTS FOR THE PARAMETERS MEASURED IN THE SUPPRESSIVE SHIELD TESTS

CHANNEL NO.	MEASURED PARAMETER	UNITS
1	Internal peak reflected pressure	MPa (psi)
2	Internal quasi-static pressure	MPa (psi)
3	External overpressure, 90° to right of door	KPa (psi)
4	External overpressure in front of door	KPa (psi)
5	Strains, at suface of sphere	Microstrains
6	Strains, at reinforcing band	Microstrains

The relative positions of the various instruments are shown in Figure 3, where identification is made by the channel numbers given in Table I. Channels numbered 1 and 2 recorded internal pressure from measurements made by two of the piezoelectric pressure transducers installed in the reinforcing band of the shield and just below its horizontal seam. Channel number 1 recorded the internal shock pressure and channel number 2 recorded the quasi-static pressure.

The external free-field overpressure was measured by the remaining two piezoelectric pressure transducers which had their data recorded by channels numbered 3 and 4. The pressure transducer for channel #3 was oriented to measure the incident overpressure at a point 90° to the right of the door at a distance of 60.96 cm (24 in.) from the external surface of the shield and in the plane in which the horizontal seam is located. The other free field overpressure transducer(channel #4) was located in a similar manner except it was directly in front of the port. The locations of the transducers were designed to discern explosive gas leakage through the port.

The remaining two channels recorded the strain measurements made by the two strain gauges. Channel number 5 recorded measurements made by a strain gauge located at a non-reinforced point on the shield where the strain was expected to be most pronounced. This gauge was oriented so that it would measure strain in a longitudinal direction on the spherical shield. The remaining strain gauge whose measurements were recorded on channel number 6, was positioned at the reinforcing band. It was oriented so that it would measure strain in a latitudinal direction. This strain gauge was for the purpose of detecting any local deformation due to the close proximity 7.62 cm (3.0 in) of this position to the charge array located on the revolving platform.

IV. TEST PROCEDURE

The test procedure consisted of performing a test on the suppressive shield by detonating an amount of high explosive located inside it, analyzing the results of physical measurements and, if no permanent damage was sustained, to repeat the test with a greater amount of explosive. A chronological listing of nine tests performed in this manner is presented in Table II. The table includes the various charge configurations and the total charge weights. The smallest charge weight tested was 28 gm (0.988 ounces) and the largest charge weight tested was 483 gm (17.037 ounces).

Figure 4 presents a diagram of the top view of a typical arrangement of the charges on the platform. In the first six tests, the charges of 50/50 pentolite explosive were positioned on the supporting platform in a circular array. The centers of mass of the charges in the circular array were located on a circle with a radius of 22.86 cm (9 inches). Since the radius of the suppressive shield is 30.48 cm

TABLE II. THE CHARGE CONFIGURATIONS AND TOTAL CHARGE WEIGHT USED IN THE SUPPRESSIVE SHIELD TESTS

TEST NUMBER	NUMBER OF CHARGES	SEPARATION DEGREES	TOTAL CHARGE WEIGHT GRAMS	OUNCES
1	2	180	28	0.988
2	2	180	28	0.988
3	5	72	70	2.469
4	10	36	140	4.938
5	19	18.9	266	9.383
6	24	15	336	11.852
7	1	central	356	12.557
8	1	central	358	12.628
9	1	central	483	17.037

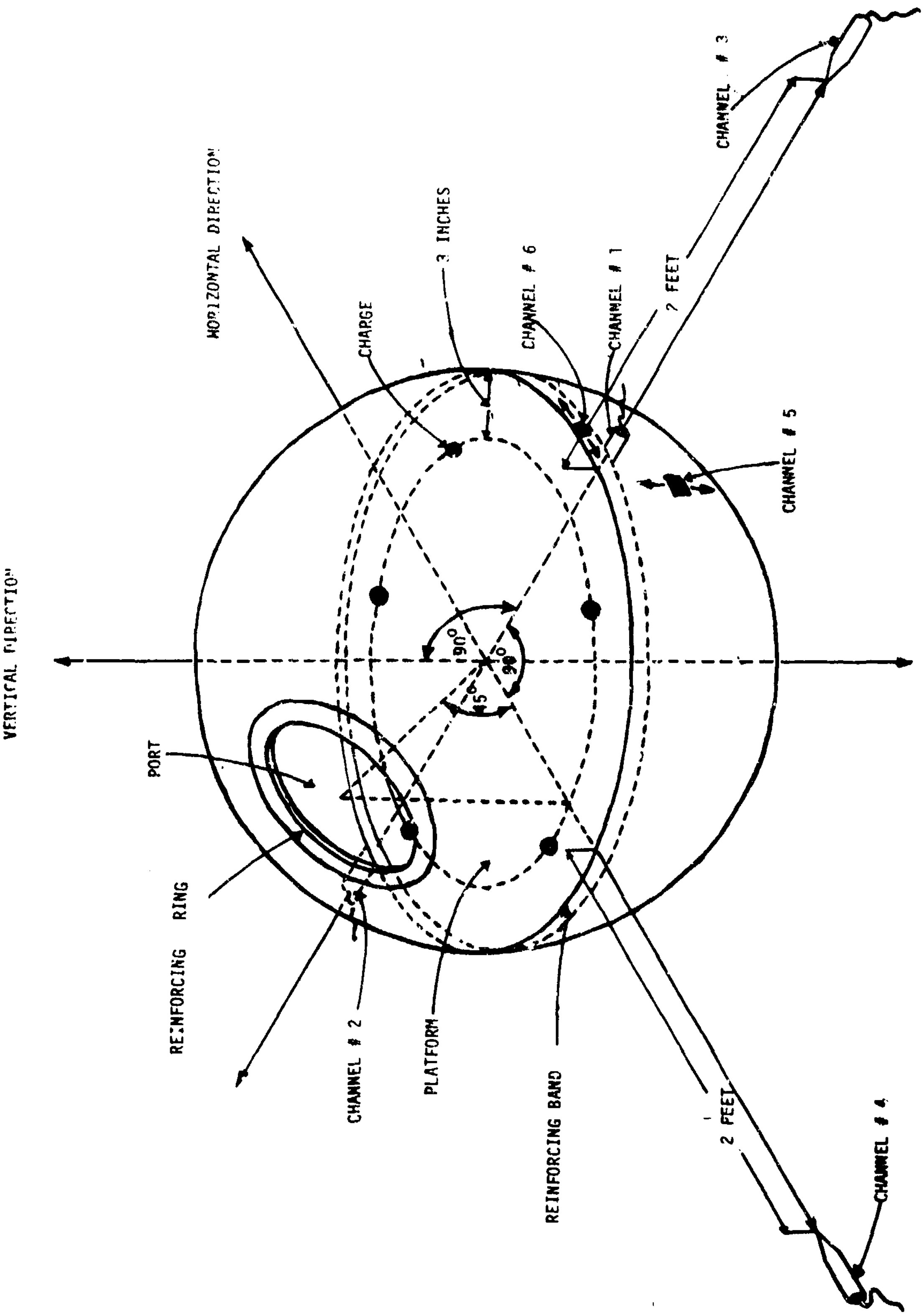

FIGURE 3: The Relative Positions Of The Measuring Devices On The Suppressive Shield

(12 inches), the center of mass of the charges were 12.7 cm (3 inches) from the wall of the shield. The charges were placed at equal distances from each other around the circular array. In Tests 1 and 2, the two charges were placed 180° apart directly in front of each of the internal pressure transducers. In the remaining four tests (Tests 3,4, 5, and 6) the number of charges were 5 or more and no attention was paid to the locations of the charges with respect to the positions of these pressure transducers.

Nearly simultaneous detonation of the spherical charges was accomplished by passing a detonating cord through all of the charges and initiating them with a single detonator.

In the last three tests performed in the series, a single charge was used and the center of mass of these charges were placed at the center of the supporting platform. Following each test the shield was visually inspected for evidence of permanent deformation or other physical damage.

V. TEST RESULTS AND ANALYSIS

The test results obtained in the nine tests on the suppressive shield are summarized in Table III. In general, the results follow patterns which are expected for these kinds of tests but some of the measurements are not well behaved. These patterns are discussed below. In those cases where the value measured is entirely unrealistic, an asterick replaces the value in the table. Test problems invalidated the first test, therefore test number 2 is a repeat of the first test. In the first test, the seal around the door leaked excessively because the door failed to close properly. In the second test, the situation was corrected and realistic results were obtained. Overall, it was expected that the measurements on all of the six instruments would tend to increase in proportion to increases in the total charge weight. That expectation is partially realized.

The peak reflected pressures recorded on Channel 1 lacked significant correlation with the total charge weight. This is partially attributed to the interaction of direct shock waves generated by the detonating charge and the shock waves reflected off the various structural members present in the sphere. In addition, as the number of individual charges were increased, the distance between the nearest charge and the pressure transducer varied. In test number 2, a charge was placed directly opposite the pressure transducer and a relatively high peak pressure value was obtained. In later tests, that distance could have been greater. Also, as the number of charges increased, the shock pattern was more complicated and the probability of various shocks combining increased. The highest peak pressure was obtained in test number 8, where the total charge weight was 358 grams of high explosive. Even with the resulting high value of 45.5 MPa (6600 psi).

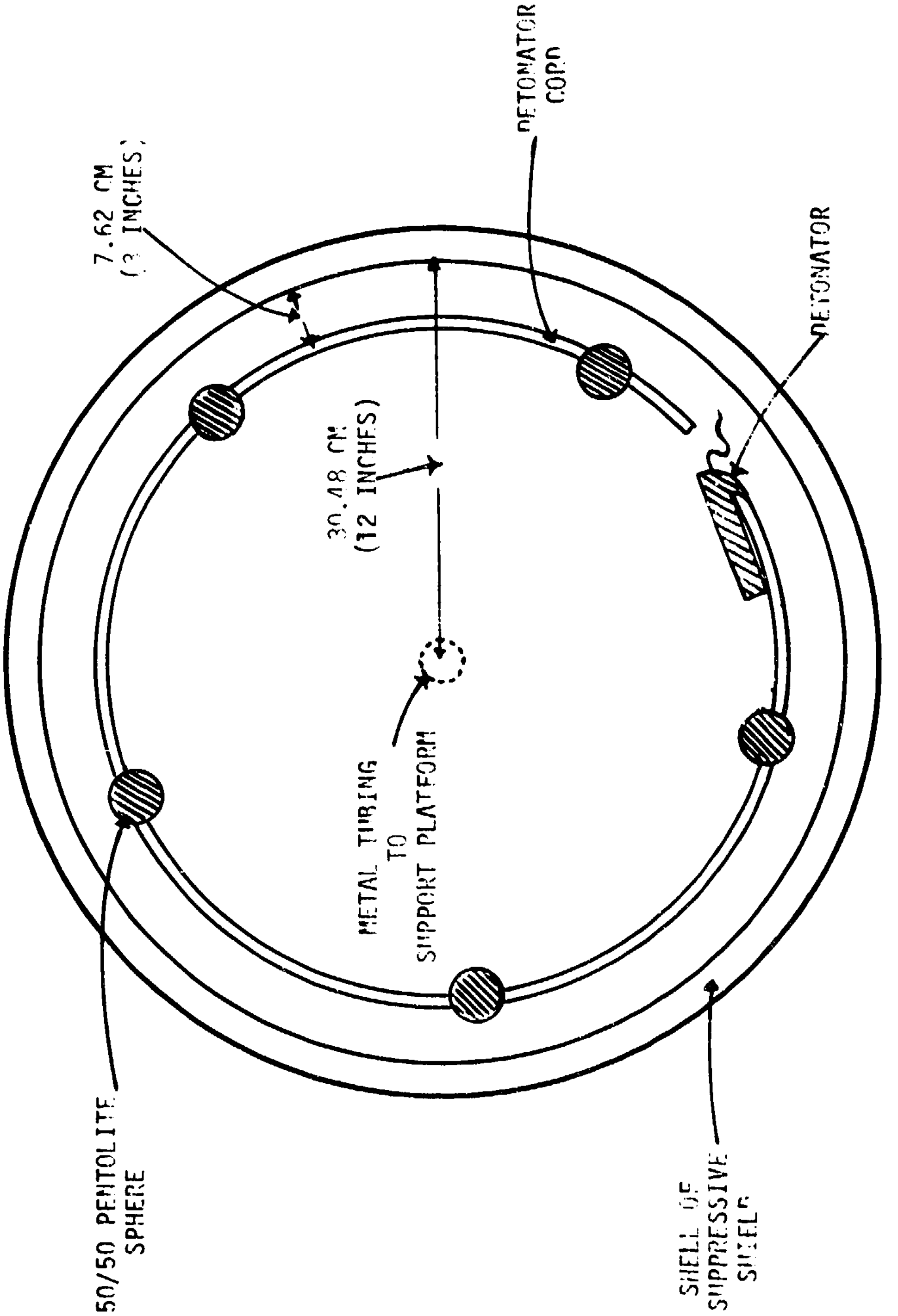

Figure 4: A Typical Arrangement Of The Spherical Charges In The Suppressive Shield

TABLE III. A SUMMARY OF THE PRESSURE AND STRAIN DATA OBTAINED IN THE SUPPRESSIVE SHIELD TESTS

Parameter	Channel	Units	1	2	3	4	5	6	7	8	9
		Test No.	1	2	3	4	5	6	7	8	9
		No. of Charges	2	2	5	10	19	24	1	1	1
		Charge Wt (gm)	28	28	75	143	257	321	356	358	483
Reflective Pressure (Peak)	1	MPa	19.5	24.1	10.3	9.7	13.8	*	*	45.5	*
		psi	2828	3495	1493	1400	2000	*	*	6600	*
Quasi-static Pressure (Peak)	2	MPa	*	0.79	1.31	2.34	3.38	4.14	*	4.83	*
		psi	*	115	190	340	490	600	*	700	*
Exterior Overpressure (90° to side)	3	KPa	6.9	1.7	1.0	2.8	2.4	1.7	3.4	1.4	6.6
		psi	1.0	0.25	0.15	0.4	0.35	0.25	0.5	0.2	0.95
Exterior Overpressure (Front)	4	KPa	9.0	4.1	1.4	5.2	6.6	5.9	3.1	2.8	7.2
		psi	1.3	0.6	0.2	0.75	0.95	0.85	0.45	0.4	1.05
Strain (Longitudinal)	5	Micro-strains	1300	850	900	2000	1900	2200	2400	2800	4000
Strain (Longitudinal)	6	Micro-strains	350	250	400	500	650	500	1500	1650	2000

*An asterisk a case where an invalid test measurement was obtained due to damage sustained by the test instrument or the signal line.

the suppressive shield maintained its integrity and no permanent deformation of the reinforcing band resulted.

The quasi-static pressures, measured by one of the internal pressure transducers and recorded on channel 2, behaved well in that the values increased uniformly as the total charge weight increased. An example of a record is presented in Figure 5. The actual value taken to be the quasi-static pressure is the peak value of a visually drawn curve through the recorded data. As the record indicated, the pressure build-up dropped relatively slowly indicating that suppressive shield was able to retain the explosive gases so that blast effects exterior to the shield were minimal.

The peak strain values recorded on channels 5 and 6 increased in direct proportion to the increase in the charge weight. The structural strain records are characterized by strong vibrational resonances induced in the wall of the suppressive shield, superimposed on a tensile strain caused by the relatively gradual buildup of pressure. The strain magnitudes subsided to zero in 15 to 20 milliseconds as the vibrations and internal pressure dissipated. The peak strain values obtained at the surface of the shield were consistently higher than those at the reinforcing band, thus, illustrating the strengthening effect of the reinforcing band. Following each test, the inspections of the shield failed to reveal any permanent damage and the instruments recorded no significant residual strain in the shield's structure.

The peak external pressure values recorded on channels 3 and 4, do not reflect any increasing trend corresponding to increasing explosive charge weight. The random nature of the data suggests that the major source of the external pressure levels is the acoustic wave generated by expansion of the suppressive shield. On the average, the pressure values for the pressure transducer in front of the port is 1.7 times the average value obtained with the pressure transducer located at 90° with respect to the port. The higher values obtained in front of the port is attributed to some leakage around the seal of the door. The important fact, however, is that none of the values surpassed the threshold needed to cause human eardrum rupture. Even the 9.0 KPa (1.3 psi) resulting from the door not sealing properly on the first test is far below the 34.5 KPa (5 psi) threshold.

VI. CONCLUSION

The results of this study indicate that the prototype suppressive shield constitutes a feasible method in terms of safety for transporting explosive charges in close quarters among working personnel. The suppressive shield retained its integrity throughout all of the tests and was able to contain detonation products of exploding charges weighing up to 483 gm (17.037 ounces). No eardrum rupture would have been sustained by anyone located at least 60.96 cm (24 inches) from the suppressive shield's exterior surface, even if they had been situated directly in front of the port.

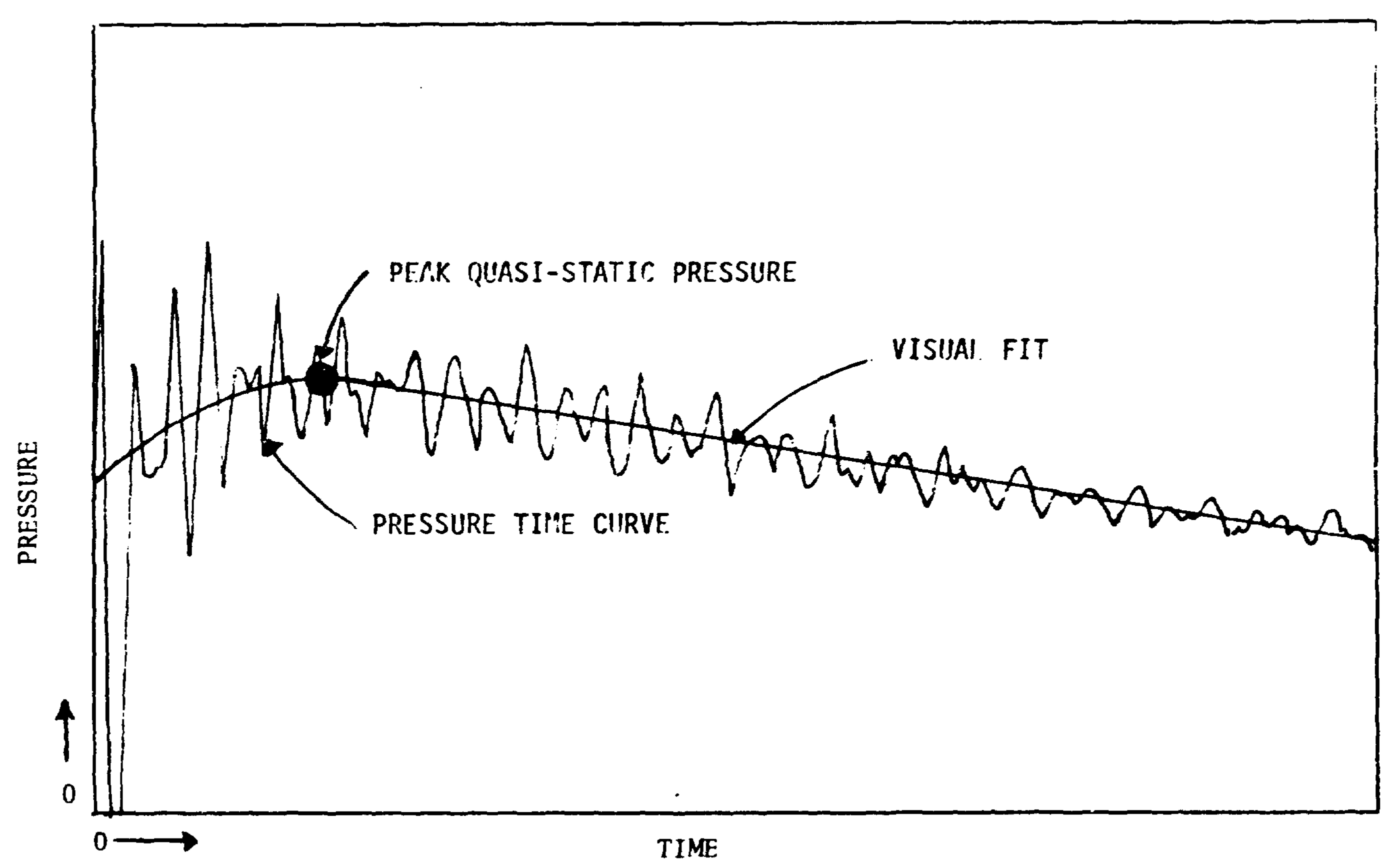

Figure 5: An Example Of the Quasi-static Pressure Measured Inside The Suppressive Shield

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